

Figure 7.—Cut sequence for 5660 and 5750 sublevels showing location of instrumented intersection.

cut 9 to protect miners from a possible fill collapse following the collapse of a 3-m (10-ft) section of the wall in the northwest intersection corner that exposed 1.5 m (5 ft) of the side of the fill. This was 3.7 m (12 ft) from the West 1 instrument location, so the collapse did not affect instrument readings. Later, another cap was installed across the muck bay side of the intersection when a crack in the backfill was noticed there. Monitoring the instruments continued to April 2, 1998, during mining of three successive cuts below the instrumented backfill location.

Changes in the truss leg readings on March 1, 1998, indicated that the intersection had failed. Visual inspection revealed that the northwest corner of the intersection had collapsed on to the top of the cut 9 fill in the same area where the stope wall had failed during mining of cut 9. At this time, the active mining face was 9 m (30 ft) below with two backfill horizons between it and the failed backfill, so the failure posed no hazard to the miners.

IN-MINE OBSERVATIONS AND DATA ANALYSIS

CLOSURE READINGS

Stope wall closure readings were taken in the mining cut, across the backfill, and in the gap above the backfill between rock bolts to determine horizontal convergence of the stope walls as mining progressed. The closure instruments showed that the walls of the slot and vein were converging, but that the walls of the muck bay were not moving.

String pots placed in the backfill showed the vein walls had converged an average of 7.9 cm (3.1 in) during mining of cut 9 on the 5660 level, 8.9 cm (3.5 in) during mining of cut 1 on the 5750 level, and 8.0 cm (3.2 in) during mining of cut 2 on the 5750 level. At the same time, vein closure measured by string pots in the gap area averaged 14.0 cm (5.5 in) for cut 9 on the 5660 level, 11.5 cm (4.5 in) for cut 1 on the 5750 level, and 9.7 cm (3.8 in) for cut 2 on the 5750 level. Increased amounts of closure across the gap were caused by a lack of support for the walls in this area. Gap closure also began 1 or more days

before closure in the backfill (figure 8), a further indication that the backfill was supplying wall support. The amount of overall wall closure would probably be the same, but the backfill supplied enough support so that fractures in the stope walls closed before the backfill started to yield. There were no borehole closure extensometers in the walls, so this hypothesis could not be confirmed.

In the active mining area, a tape extensometer recorded an average of 9.4 cm (3.7 in) of convergence across the vein and 7.6 cm (3.0 in) across the slot. Closure measurements in the active mining area began after mining was at least 9 m (30 ft) past the instrument locations; therefore, these measurements do not represent total closure related to mining of this cut.

A thrust-fault-type of fracture (figure 9) was noticed at the top of the backfill while retrieving the CR10's data canister on November 4, 1997. The failure went across the intersection and into the east and west headings along the vein. Both 2- and 2.4-m- (6- and 8-ft-) long vertical rock bolts had been placed in

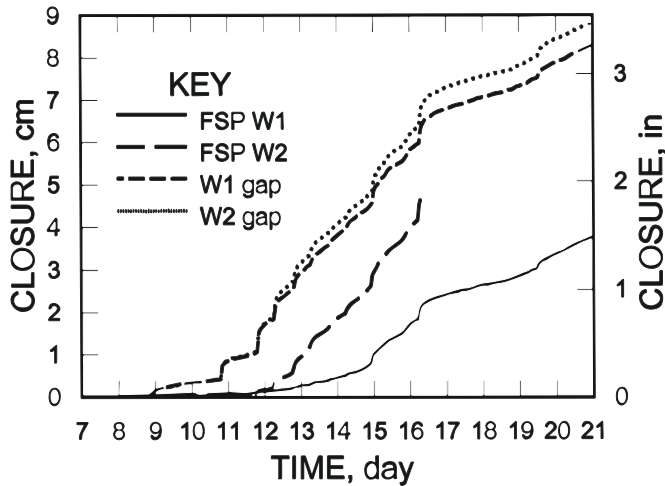


Figure 8.—Gap and backfill closure versus time.



Figure 9.—Thrust-fault-type failure, November 4, 1997.

the area. Failure appeared to be above the 2-m (6-ft) rock bolts, but blocked by the 2.4-m (8-ft) rock bolts, the ends of which were just visible at the top of the fill.

This failure was caused by convergence of the vein walls on the backfill. At this time, there had been 2.5 to 7.6 cm (1 to 3 in) of horizontal closure across the vein in the backfill and 7.6 to 15 cm (3 to 6 in) in the gap above the instrumented backfill.

Fracturing of the backfill caused upward buckling that gradually reduced the gap between the backfills over time. Buckling continued until the initial 1-m (3.5-ft) vertical gap was reduced to less than 0.3 m (1 ft) before the backfill from cut 7 collapsed onto the instrumented cut 8 backfill. Table 1 is a summary of original stope widths, and table 2 shows closure readings for the three mining cuts. Figure 10 shows backfill closure as a function of time for three mining cuts. Total closure includes

some rapid closure as the cut was mined past the instruments and more gradual time-dependent closure resulting from all previous mining in the area.

Table 1.—Original stope widths.

Location	m	in
West 1	34.5	136
West 2	25.4	100
East 1	27.4	108
East 2	36.6	144
Muck bay	39.6	156
Slot 2	30.0	118
West 1	52.1	205
West 2	35.6	140
East 1	37.1	146

TESTS OF CEMENTED BACKFILL SPECIMENS

At the time the stope was backfilled, samples of the fill were collected for compressive and tensile strength tests. The 7-day unconfined compressive strengths ranged from 1703 to 2744 kPa (247 to 398 psi), with an average of 2082 kPa (302 psi), while 28-day unconfined compressive strengths ranged from 2654 to 3902 kPa (385 to 566 psi) and averaged 3254 kPa (472 psi). The laboratory tests agreed with the 2757-kPa (400-psi) ultimate strength recorded across the vein at approximately 15 days.

Movement of the platen head of the compression test machine was also recorded to determine an apparent modulus for the 7- and 28-day compressive tests. Figure 11 is an example of the stress-strain curve for the tests. The modulus for the samples is calculated between the 20% and 50% strength values because this is the straight line portion of the curve and most representative of the true response of the backfill. The equation used is —

$$\begin{aligned} \text{20-50 modulus} &= (50\% \text{ strength} - 20\% \text{ strength}) \\ &\div (50\% \text{ strain} - 20\% \text{ strain}). \end{aligned}$$

The five samples tested at 7 days had a range of apparent modulus from 593 to 2013 MPa (86,000 to 292,000 psi) with an average of 1041 MPa (151,000 psi). Apparent modulus for the 28-day tests ranged from 1172 to 1641 MPa (170,000 to 238,000 psi) and averaged 1370 MPa (198,700 psi).

Seven-day tensile strengths ranged from 441 to 551 kPa (64 to 80 psi) and averaged 496 kPa (72 psi), while the 28-day tests ranged from 537 to 579 kPa (78 to 84 psi) and averaged 551 kPa (80 psi). These strengths are consistent with other tests recently conducted on samples of cemented fill from the Lucky Friday Mine. Appendix A provides a summary of recent tests.